Habitat Associated With Home Ranges of Female *Odocoileus virginianus* (Mammalia: Cervidae) in Eastern Kentucky

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ABSTRACT.— Modified minimum-area home ranges were estimated for eight does of the white-tailed deer, *Odocoileus virginianus*, relocated from bottomland hardwood habitat of western Kentucky to the Cumberland Plateau of eastern Kentucky and for six does resident to eastern Kentucky. Mean size of home ranges was similar for resident (642 ha) and relocated (668 ha) does. Data obtained on vegetation, land use, and topography from a computerized Geographic Information System (GIS) indicated that home ranges of resident does included more bottomland habitat than was randomly available ($P < 0.03$) and that those of relocated does included more young forest than was randomly available ($P < 0.05$). GIS may be an economical tool for identification of future release sites.

Populations of white-tailed deer, *Odocileus virginianus* Rafinesque, have been increasing throughout most of Kentucky (Phillips 1983) except on the Cumberland Plateau in the east. Previous attempts to reintroduce 40-50 deer per county in this area have failed to produce a herd near carrying capacity (Phillips 1983). Stocking 400-500 deer per county is being attempted on the Cumberland Plateau, by the Kentucky Department of Fish and Wildlife Resources, to establish viable populations.

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The release of deer into areas of high-quality habitat may reduce dispersal and increase the probability of successful stocking (Pais 1987). The existence in eastern Kentucky of a computerized Geographic Information System (GIS) based on maps and remotely sensed data allowed us to characterize the habitat within home ranges of white-tailed deer. We know of no data on size or habitat characteristics of home ranges of these deer in eastern Kentucky prior to this study.

In this study we proposed to compare the size of home ranges of resident and relocated does in eastern Kentucky, to characterize the features of the home ranges according to GIS categories, to compare the relative abundance of these features on actual and randomly available home ranges for resident and relocated does, and to characterize areas that should be considered as future release sites.

STUDY AREA AND METHODS

The trapping site of the white-tailed deer that were to be relocated was the Ballard County Wildlife Management Area (WMA) in western Kentucky. Ballard Co. topography ranges from flat to moderately rolling, with a maximum relief of 55 m. The natural forest type in the WMA, which is adjacent to the Ohio River, is bottomland hardwood. Millet (*Echinochloa walteri*), soybeans (*Glycine max*), and corn (*Zea mays*) have been planted to attract waterfowl. Estimated density of white-tailed deer on the WMA in 1986 was 1/1.5 ha according to the DPOP2 deer population model for microcomputers (Phillips 1985).

The release sites were in Knott Co., Ky., in the central Cumberland Plateau. Local relief of 200-350 m is common. Cliffs occur on surface mines and highway road-cuts. Approximately 80% of the county is forested, 10% is reclaimed or active surface mines, and 10% is bottomland with little agricultural land present. Roads and houses occur primarily in bottomlands. The forest type is mixed mesophytic, with most stands 40 to 60 years old.

Resident white-tailed deer came from the University of Kentucky's Robinson Forest in Breathitt Co. and Knott Co. Robinson Forest is similar in topography and vegetation to the release sites in Knott Co., but there has been no surface mining and it has been closed to the public for 10 years.

Knott Co. was closed to hunting during the period of deer stocking in 1983-85 but was opened to regular statewide seasons in the fall of 1985. Prior to the deer releases in 1983, Knott Co. supported <1 deer/600 ha according to the DPOP2 model (Phillips 1985).

During 1983-85, 485 deer were relocated to Knott Co.; they were generally moved in lots of 25. For this study, which was conducted in 1984-85, radio-collared relocated does were released during 1985 in

three locations in the county: 6 on 6 February at Vest, 11 on 22 February at Knob Bottom, and 18 on 13 March at Carr Fork. Only 8 of these 35 radio-collared does were used in the analysis reported here, because not all does survived and established home ranges. In addition, resident does were captured between November 1984 and April 1985 in Robinson Forest; these does were also radio-collared, and 6 were used as controls for the relocated does in this analysis.

Does slated to be relocated were captured in rocket nets, in Stephenson box traps, and with rifle-propelled darts containing succinylcholine chloride. We attached radio collars at the time of capture. The does captured at Ballard County WMA were kept for up to 5 days prior to shipment in a modified barn designed to reduce stress and limit human contact. The interior of the barn was dark, and does were provided with food and water through panels removable to the barn's exterior. They were loaded for shipment by slowly rolling one of the barn walls toward a loading ramp until all individuals entered a waiting truck. The does were not immobilized during shipment.

The three release sites were chosen by local conservation officers. The criteria for their selection were that local interest in the stocking be high and that the probability for harassment of the does by dogs and people be low. Consequently, most release sites were remote.

Resident does were captured with rocket-nets in clearings baited with corn or salt. We immobilized the deer with intramuscular injections of xylazine hydrochloride (0.01 mg/kg of body weight) so that radio collars could be attached. The deer were then released at the point of capture.

Radio collars had a life expectancy of at least one year. Constructed of brown nylon, they were permanently attached to each doe. A three-element H-type antenna was used for aerial and ground radio-tracking. Radio location vectors were taken on each resident and relocated doe within Knott Co. at least twice weekly from 6 February to 13 November 1985.

The approximate location of individuals was determined by triangulation (Cochran 1980:517-519). Vectors that crossed at angles $>135°$ or $<22°$ were not used to record locations. Hence, not all vectors resulted in fixes, and the mean number of observations/doe/week was 18.6.

The accuracy of vectors was determined by triangulating from varying distances on three transmitters of known positions at Robinson Forest and averaging the bearing precision over the mean distance. The average of the error polygons was determined using two bearings per triangulation according to the procedures of Heezen and Tester (1967; see also Nams and Boutin 1991).

We used the modified minimum-area method to estimate home ranges because it miminized the chance of including areas not used by an individual (Harvey and Barbour 1965, Mooty et al. 1987). This method is most useful with irregularly shaped home ranges, and those of white-tailed deer are usually elongated (Marchinton and Hirth 1984). The cumulative (total to date) locations recorded for each individual were plotted against each estimated home range to determine if the estimate was accurate. Locations were recorded 24 hours apart to increase the independence among observations (Swihart and Slade 1985). Home ranges were plotted only for individuals for which an asymptote was approached (Fig. 1).

The habitat of the study area was characterized with the aid of the Kentucky Department of Natural Resources' GIS. This computerized system uses information from satellite and aerial photography, U.S. Geological Survey 7.5-minute topographic maps, and site inspections to categorize habitat features over large land areas. Four GIS files, each consisting of a habitat category, were used in this study (Table 1). Appropriate sets of categories were assigned to 0.4-ha (1-acre) polygons. Fifteen 10-ha site inspections were conducted to ascertain the reliability of the GIS data in Knott Co. No discrepancies were detected.

Modified minimum-area home ranges for does were digitized onto a computer map for each GIS file. Each home range was then repositioned at random on the same 7.5-minute quadrangle map to estimate the random availability of habitat in the vicinity of the actual home range. The percentage of the total area represented by each habitat category was calculated for each home range according to the MAP model (Berry and Tomlin 1981). Because radio locations were imprecise (error polygons averaged 50 ha) relative to some map features, and because deer are highly mobile, we wished to identify home-range selection rather than selection of patches within home ranges (second-order selection of Johnson 1980). The percentages represented by each habitat category in actual randomly available home ranges of both resident and relocated does were compared by Student's *t*-tests. Data approximated normality because percentages of habitat types had narrow ranges of variability in this data set. Transformation was not necessary.

RESULTS AND DISCUSSION

We recorded 925 radio locations from approximately 1,900 bearing sets over a 3,600-km^2 area; 742 locations were of 11 relocated does and 183 were of six resident does at Robinson Forest. Most locations of relocated does revealed that the does had dispersed less than 15 km from the release site.

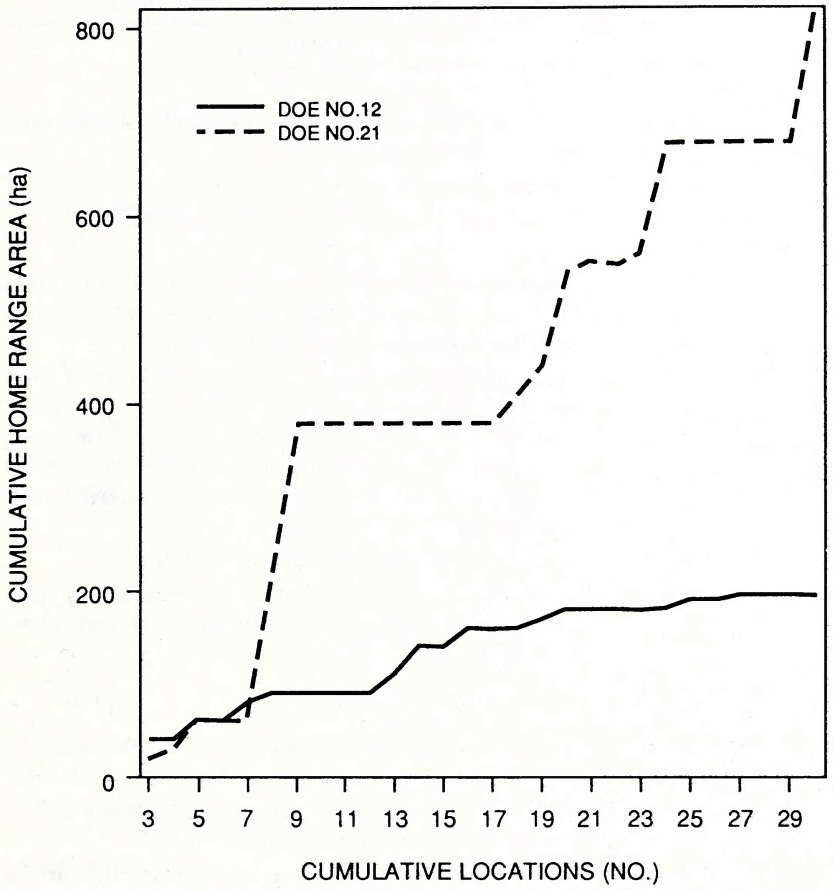

Fig. 1. Actual plotting of cumulative locations versus cumulative home-range area; note curves for defined (Doe No. 12) and undefined (Doe No. 21) home range. A home range is defined only when additional locations do not increase its area.

Triangulation was made difficult by the rugged topography of the study area. Deflection of signals from mountainsides frequently resulted in inaccurate bearings. The accuracy of bearings was $\pm 7.5°$ at 2.5 km, and the average of the error polygons was 50 ha at that distance. In a Minnesota study, accuracy of bearings ranged from 0 to 40° (Mooty et al. 1987). Most (>70%) of our locations were estimated from bearings taken <2.5 km from the animal. Poor roads and rugged topography hindered movement from one spot to the next while bearings were being taken, and some animals moved before locations could be pinpointed.

Table 1. Habitat categories in Kentucky's Geographic Information System.

Habitat category	Definition
1. Land form	
Bottomland	A flat surface adjacent to a stream and low-lying land bounded by hills or sideslopes.
Sideslope	The steeply inclined portions of a plateau.
Ridgetop	A flat surface bounded below by sideslopes.
2. Land use	
Agricultural	Areas distinguished by geometric field patterns; areas that lack activity or reflect patterns of grazing; forest openings maintained specifically for wildlife.
Human-altered	Areas intensively used by humans, with most land covered with structures; areas committed to residential use; areas of sparse residential use such as farmsteads; areas used for the sale of products and services; areas of light to heavy manufacture; mines, quarries, and gravel pits.
Natural vegetation	Areas of undisturbed indigenous vegetation.
Young forest	Regeneration of areas in which all mature trees have been cut and removed, and areas of forest lands interlaced with mines.
3. Slope gradient	
0-20%, 20-35%, 35-50%, >50%	The ratio between vertical rise and horizontal distance.
4. Vegetation	
Deciduous forest	All forests dominated by trees that lose their leaves at the end of the frost-free season.
Disturbed sites	Areas where human endeavor has changed the surface of the earth. Usually high-use areas and areas where grasses and forbs predominate. Former cropland or pastureland, now grown up in shrubs, in transition back to forest land.
Wetland	Areas where the water table is at, near, or above the land surface for a major part of the year.

Although the estimated precision of fixes was low, estimates of habitat use ought to provide a conservative comparison with randomly assigned home ranges. Error will add to among-animal variance estimates of habitat features and result in a decreased probability of detecting a difference. It is now apparent that we should have used Lenth's maximum likelihood estimators to access precision of locations; the technique was unavailable to us at the time of the study (Nams and Boutin 1991).

Table 2. Percentage of habitat in actual and randomly available home ranges of radio-collared does in Knott and Breathitt counties, 1985.[a]

Habitat category	Resident (N = 6)		Relocated (N = 8)	
	Actual	Randomly available	Actual	Randomly available
1. Landform				
Bottomland	10.1 (1.2)[b]	5.6 (1.5)	13.4 (3.1)	12.0 (2.4)
Sideslope	78.2 (1.3)[c]	79.2 (1.1)	71.9 (1.9)	72.0 (2.1)
Ridgetop	11.1 (1.8)	15.0 (1.3)	13.7 (2.4)	13.1 (3.6)
2. Land use				
Agriculture	1.2 (0.8)	0.4 (0.2)	0.0 (0.4)	0.0 (0.0)
Human-altered	0.8 (0.5)	0.4 (0.2)	3.1 (1.0)	3.7 (1.3)
Natural vegetation	95.3 (1.6)[c]	94.0 (1.9)	87.7 (3.0)	89.3 (2.9)
Young forest	3.0 (1.6)	5.2 (1.7)	3.1 (0.6)[b]	0.9 (0.3)
3. Slope gradient				
Slope 0-20%	17.0 (3.2)	20.2 (1.5)	20.0 (1.5)	20.3 (3.4)
Slope 20-35%	4.8 (2.4)	2.0 (1.0)	8.0 (2.1)	5.8 (1.9)
Slope 35-50%	78.0 (1.1)[c]	79.2 (1.1)	72.0 (1.2)	71.1 (1.9)
Slope >50%	0.2 (0.9)	0.0 (0.0)	0.0 (0.0)	1.2 (0.4)
4. Vegetation				
Deciduous forest	96.1 (1.6)[c]	95.2 (1.4)	87.5 (3.0)	88.1 (2.1)
Disturbed sites	3.6 (1.5)[c]	4.8 (1.4)	8.7 (2.2)	11.0 (2.8)
Wetland	0.0 (0.0)	0.0 (0.0)	0.7 (0.7)	0.0 (0.0)

[a] Standard errors indicated parenthetically.

[b] Variables significantly different between actual and randomly available home ranges ($P < 0.05$).

[c] Variables significantly different between home ranges of resident and relocated does ($P < 0.05$).

Home Range. Home ranges were not defined for all radio-collared does because some did not provide a sufficient number of locations (as a result of death, radio failure, or large dispersal) and because some does apparently did not establish a home range during the study. Eight relocated and six resident does established defined home ranges. Resident does averaged 23 (SE = 3.1) locations per defined home range and relocated does averaged 29 (SE = 7.4). Mooty et al. (1987) felt that 30 locations were sufficient to construct modified minimum-area home ranges for white-tailed deer in Minnesota. Sizes of home ranges for resident ($\bar{x}$ = 642 ha, SE = 132) and relocated ($\bar{x}$ = 668 ha, SE = 79) does were not significantly different ($P > 0.05$). These home ranges were large in comparison with others reported for white-tailed deer in the Southeast: 267 ha (Bridges 1968) and 80 ha (Byford 1970) in the East

Gulf Coastal Plain; 70 ha in the West Gulf Coastal Plain (Hood 1971); 58 ha in the Piedmont Upland (Marshall and Wittington 1969); 514 ha in the Ozark Highlands (Cartwright 1975); and 84 ha in the North Carolina mountains (Marchinton 1968).

Habitat Analysis. The habitat categories for which home ranges of resident does differed significantly ($P < 0.05$) from those of relocated does included sideslopes, natural vegetation, slopes between 35% and 50%, deciduous forest, and disturbed sites (Table 2). Random availability of these features also differed ($P < 0.05$) between the two samples, so resident does were not pooled with relocated does for habitat analysis.

Actual home ranges of resident does contained significantly more ($P < 0.03$) bottomland ($\bar{x}$ = 10%, SE = 1.2) than did randomly available home ranges ($\bar{x}$ = 6%, SE = 1.5) (Table 2). Wildlife openings planted with winter wheat (*Triticum aestivum*) were located in these bottomlands. Winter wheat is a preferred forage of white-tailed deer (Whitehead 1967). In eastern Kentucky, open water is found almost exclusively in bottomlands; its presence may have been a factor in the relatively high percentage of bottomland within home ranges of resident does.

Actual home ranges of relocated does had significantly more ($P < 0.05$) young forest ($\bar{x}$ = 3%, SE = 2.6) than did randomly available home ranges ($\bar{x}$ = 1%, SE = 0.3) (Table 2). Reclaimed surface mines or forest edges created by mining may have provided the does with dense shrubs for browse and cover (Harlow and Hooper 1971, Knotts 1975).

Mangement Implications. Two factors may have caused does in eastern Kentucky to have large home ranges. First, the presence of large tracts of contiguous forest may have induced the does to expand their home ranges in search of food and cover; from 88% to 95% of the habitat available to deer was deciduous forest (Table 2). Second, harassment by dogs, which has been a source of mortality of deer on the Cumberland Plateau (Anderson 1979, Pais 1987), can increase deer dispersal and may have done so in this instance.

The future success of reintroducing white-tailed deer on the Cumberland Plateau may be enhanced by choosing release sites in high-quality habitat. That the percentages of bottomlands and young forests in home ranges were higher than expected (10% and 3%, respectively) suggests that release sites need not be selected on the basis of their remoteness from human contact. Good habitat could quickly and economically be determined with the GIS. Young deciduous forest, which avergaged 3% ($\sim$ 20 ha) in the various home ranges of relocated does, was distributed in patches throughout these ranges. We therefore suggest that future release sites contain >3% young deciduous forest well distributed throughout the area in small patches.

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